CO_2 Reduction and Ocean Storage

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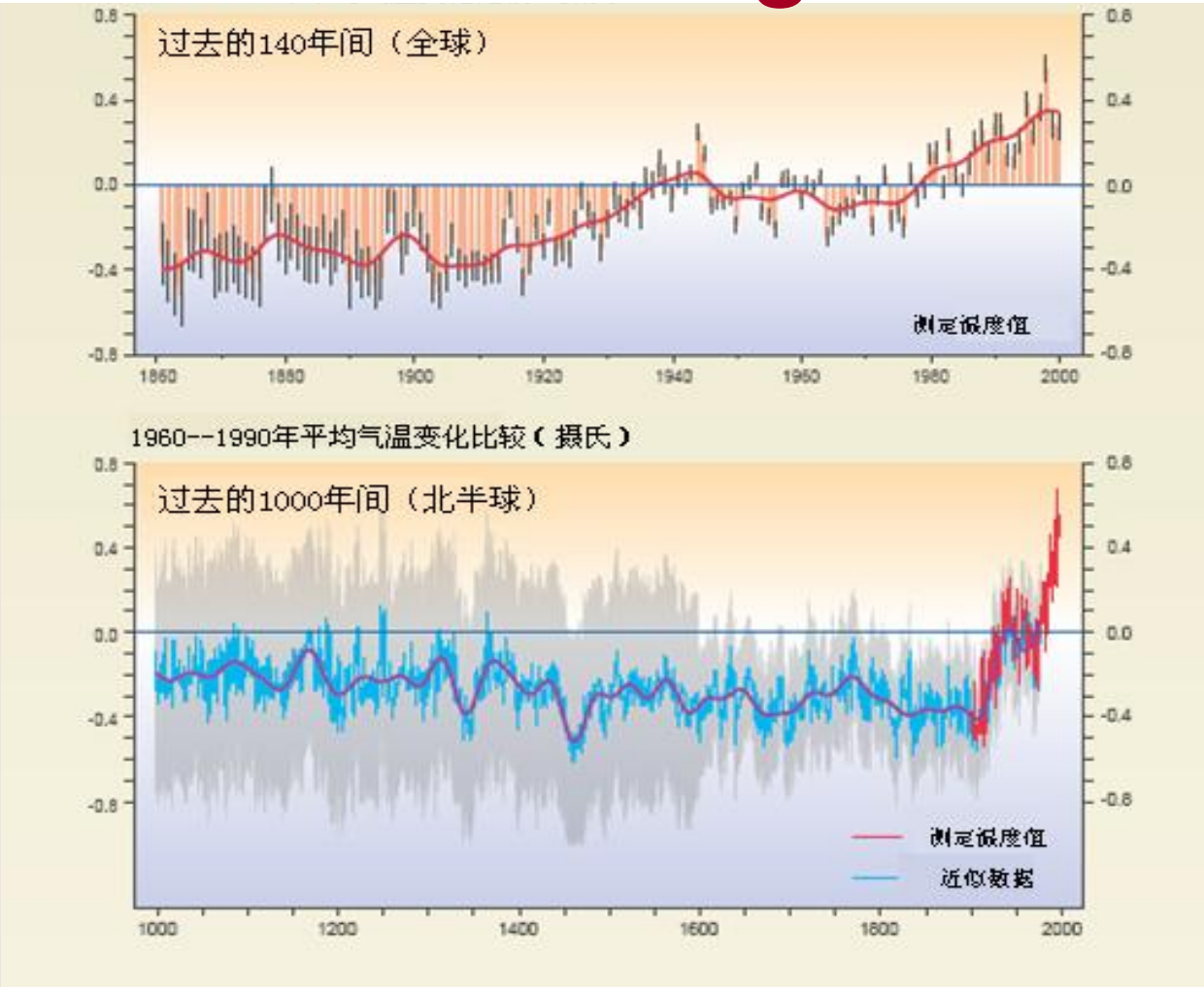
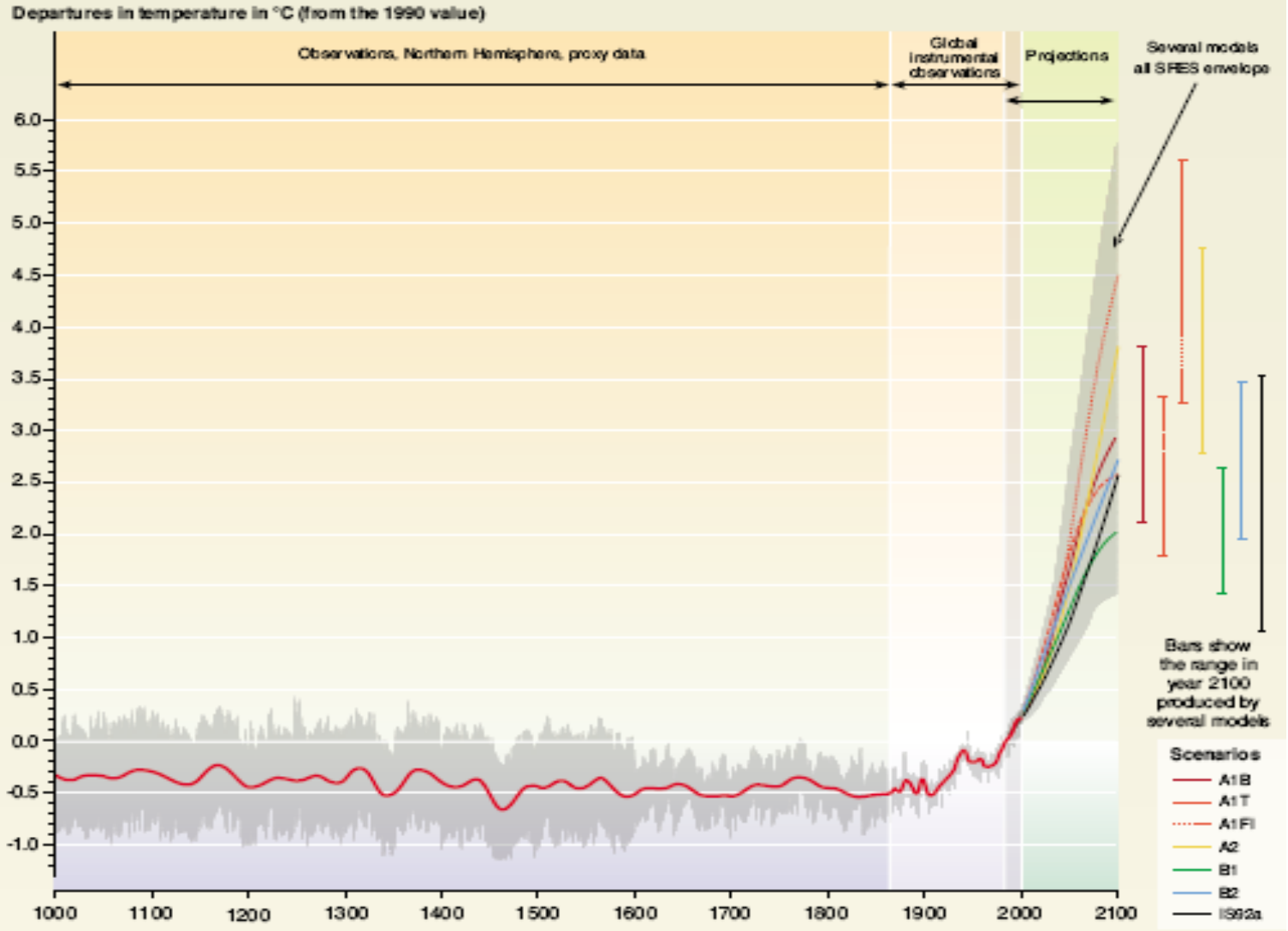
PART I Background

Global Warming Trend



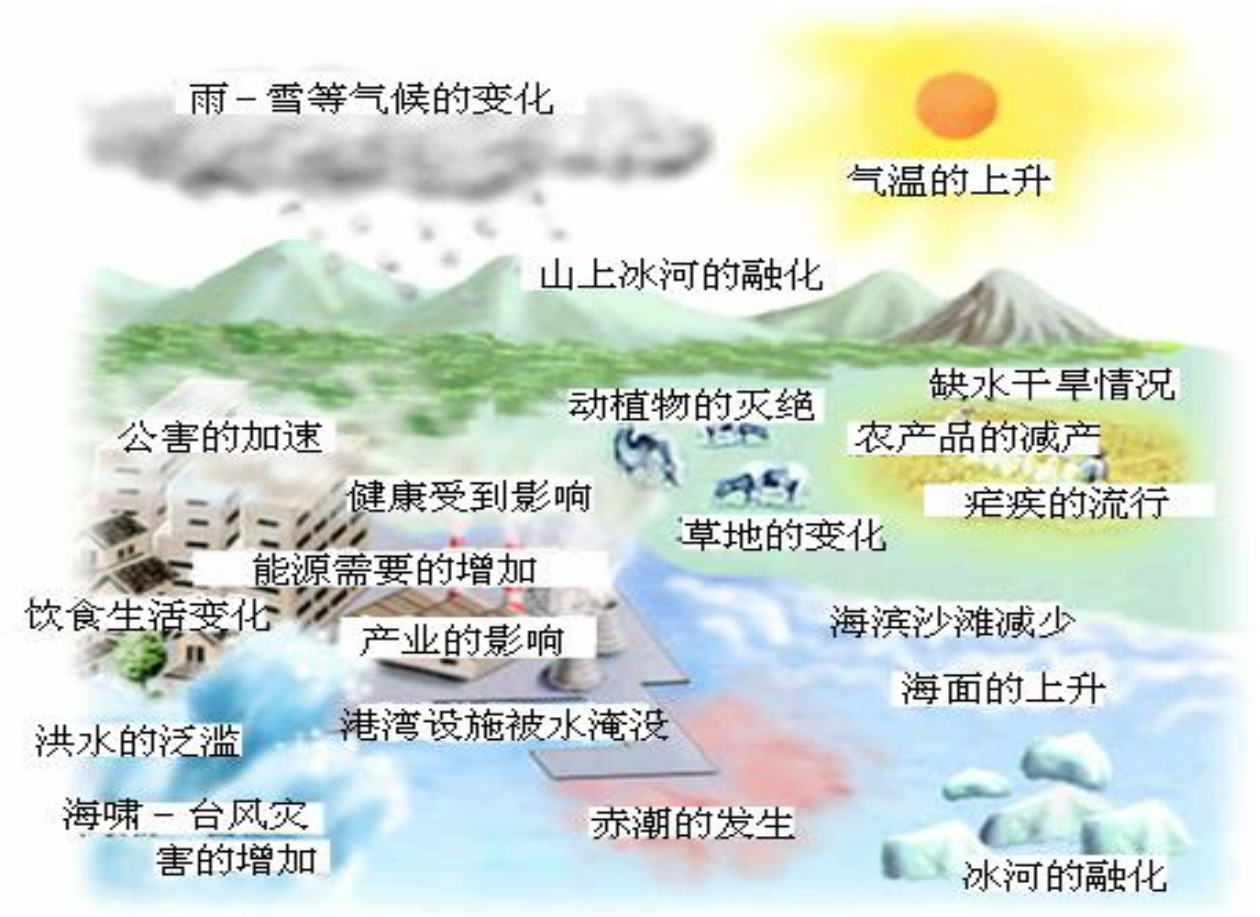
- The average ground temperature increased 0.6±0.2℃
- 1998 was the hottest year
- 20th century was the hottest in history

Variations of the Earth's surface temperature: years 1000 to 2100



IPCC Third Assessment Report: Climate Change 2001

Effects of Global Warming to the earth



Glacier Collapsed in Argentina due to the Global Warming (2004-03-16 14:01)

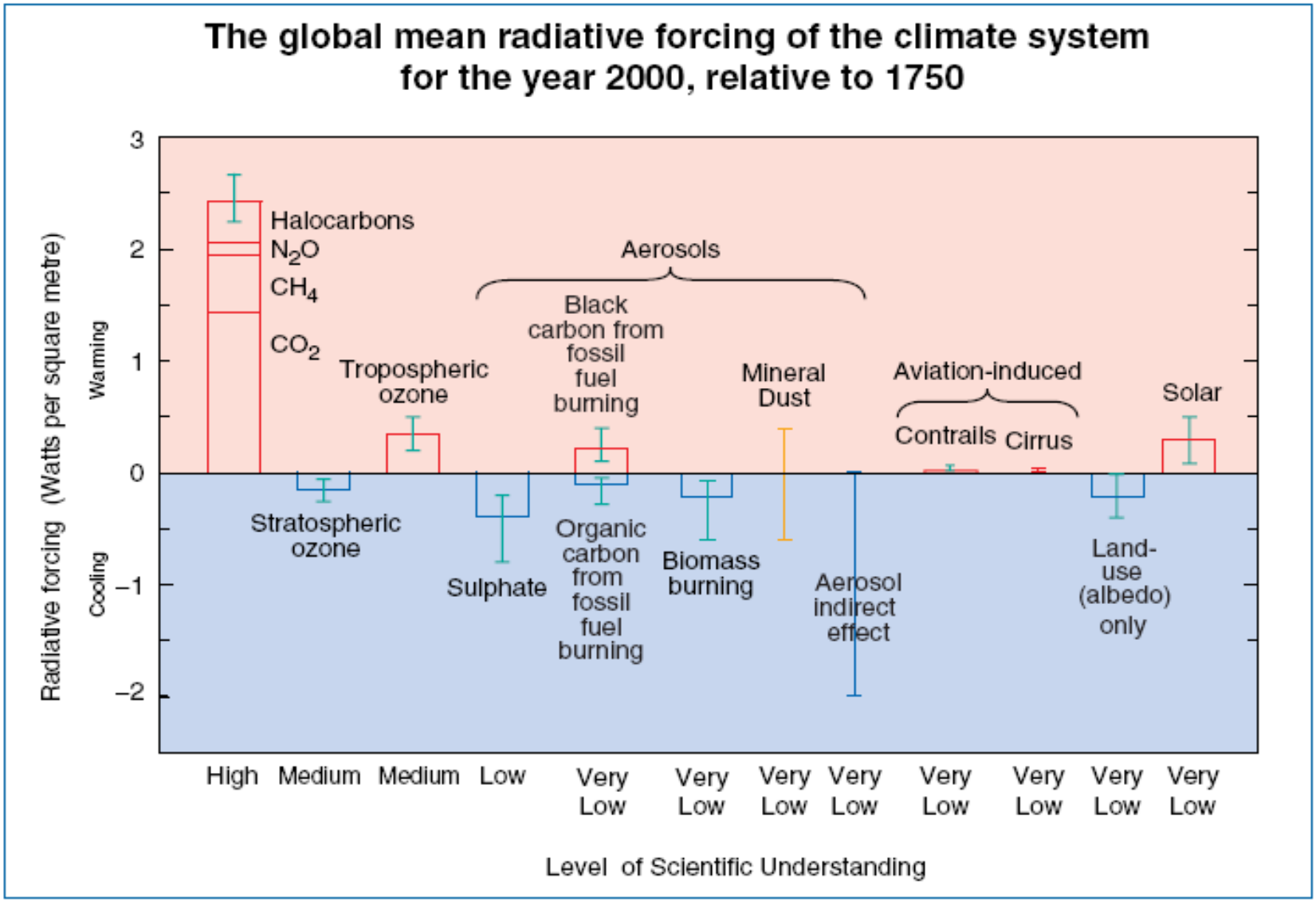
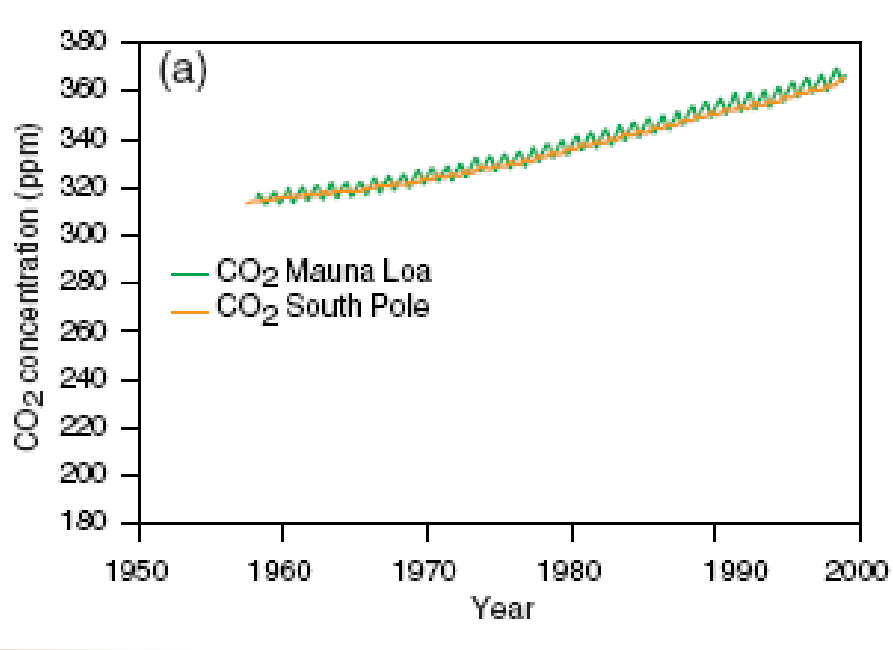
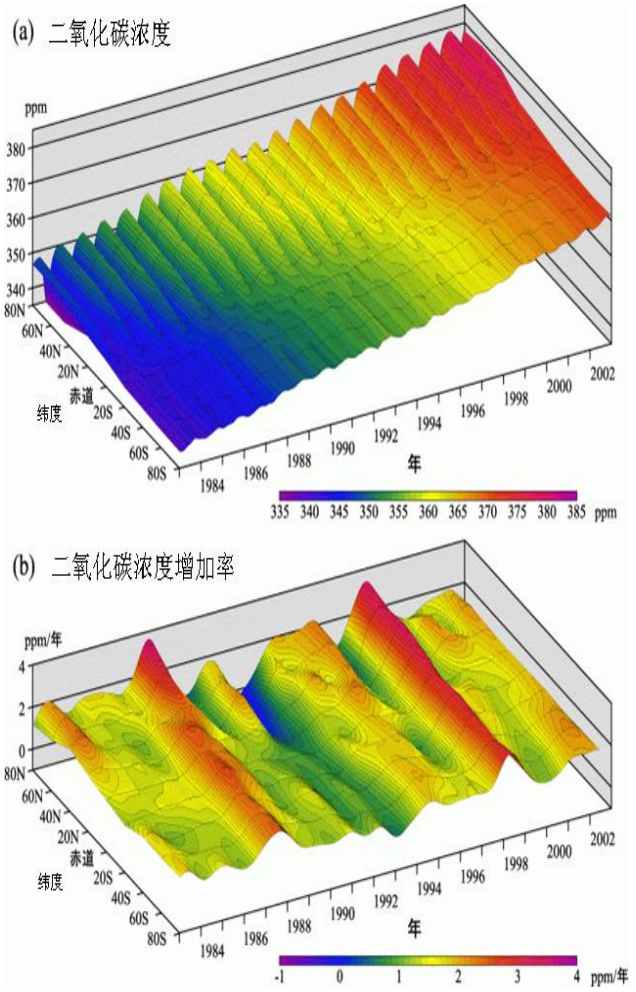


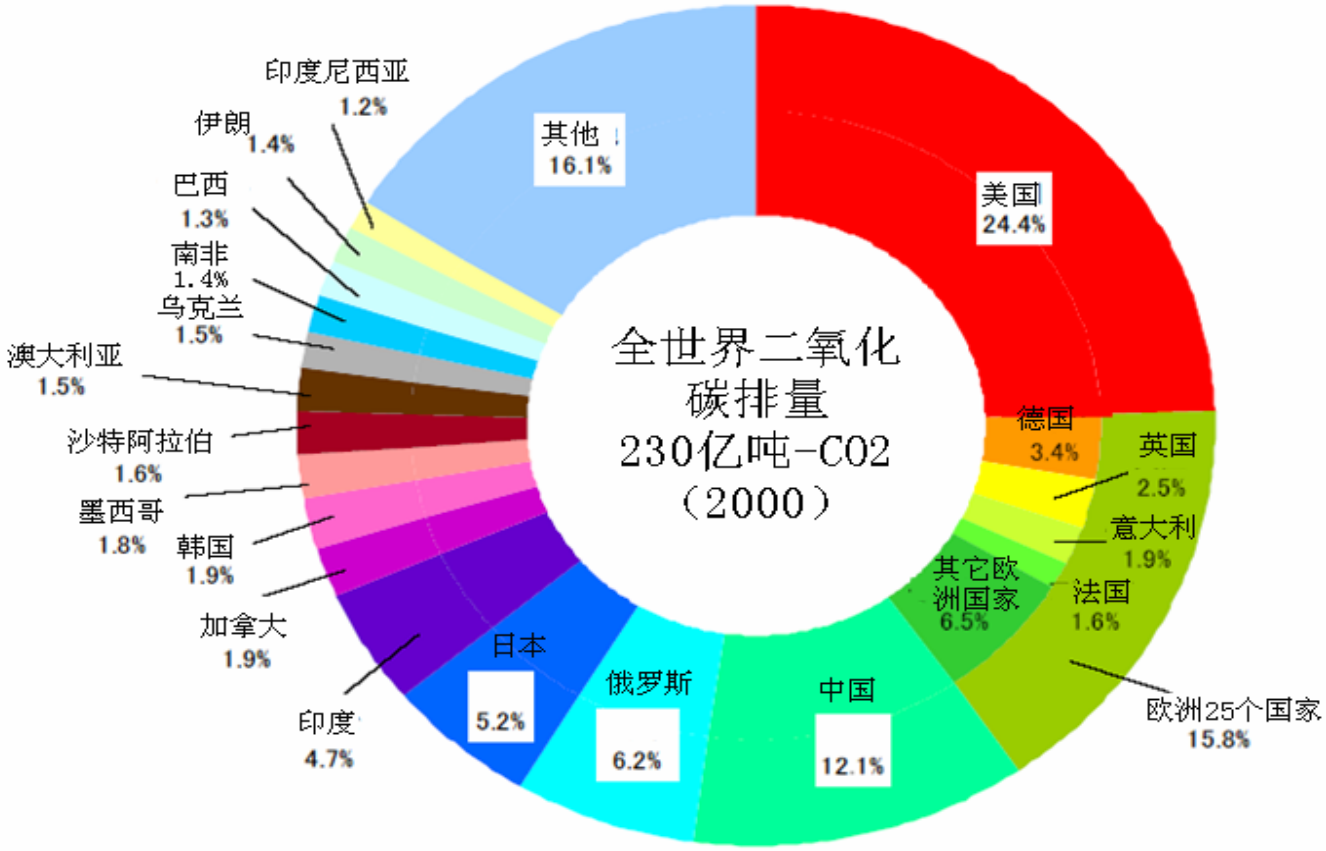
Figure 3: Many external factors force climate change.

Variations in atmospheric CO_2 concentrations



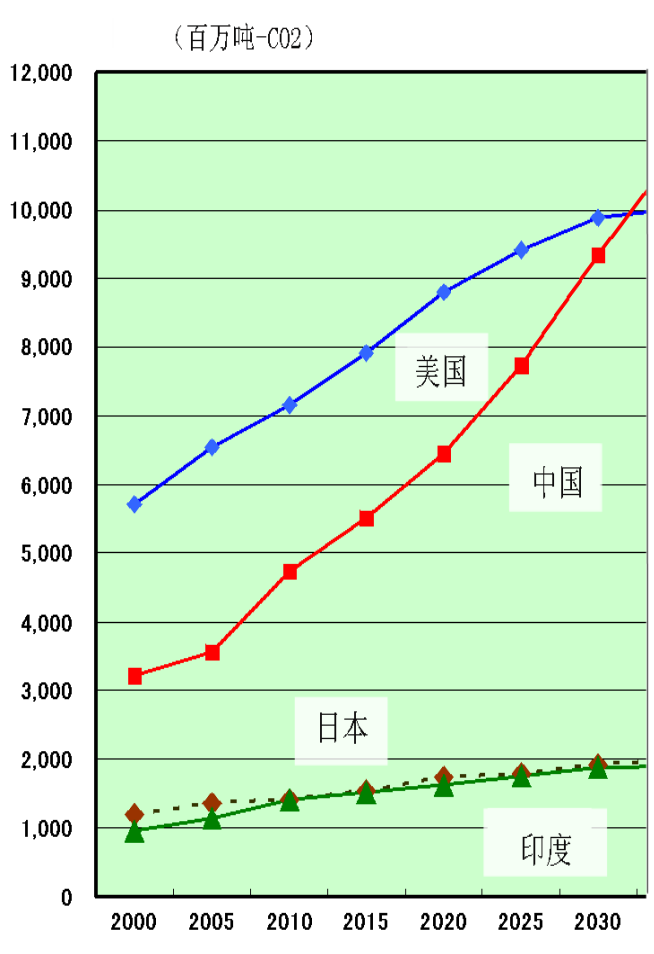


The world CO_2 production （2000）

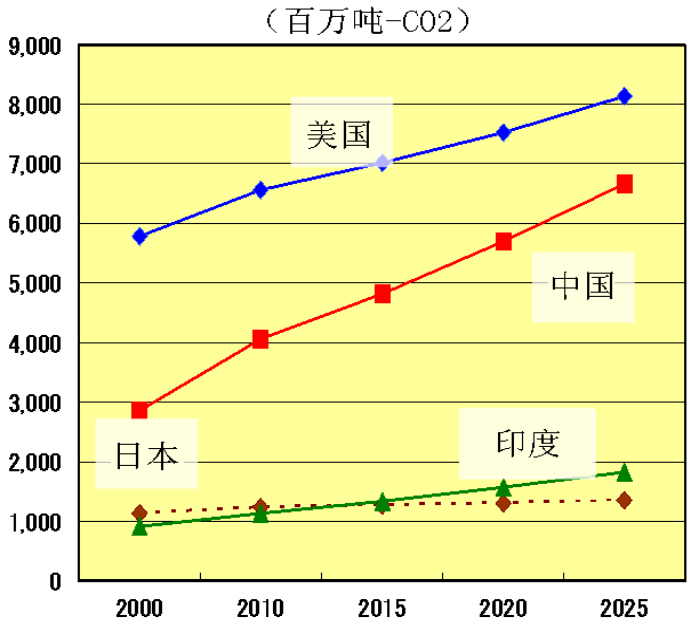


出处：美国奥克里季（Oak Ridge）研究所提供数据

CO_2 production prediction on the developing countries



Japan RITE prediction model



USA Energy Department prediction model

The world is trying to control the CO_2

According to the 1997 Kyoto Protocol，to 2012, the amount of 6 green-house gases emission by the developed countries should be decreased by 5.2% compared with 1990.

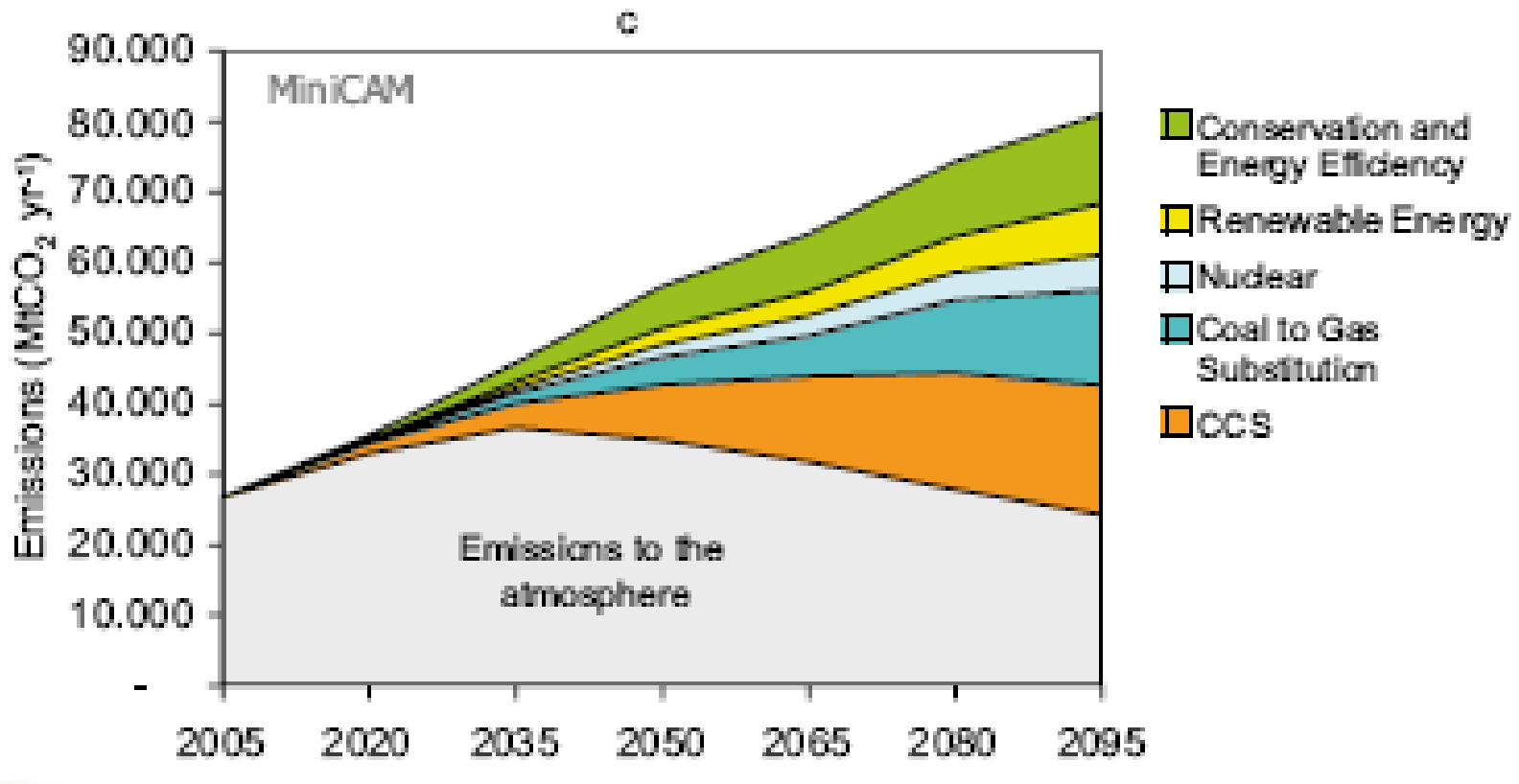
USA	-7%	East Europe	-5%~8%
Japan	-6%	Ireland	+10%
EU	-8%	Australia	+8%
Canada	-6%	Norway	+1%

Developing Countries NO forced limitation.

Green Environmental Protection Technologies
- CO_2 Abatement Technologies-

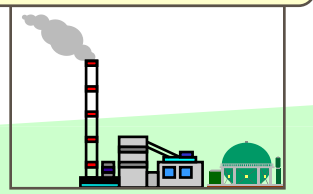
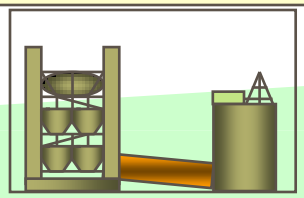
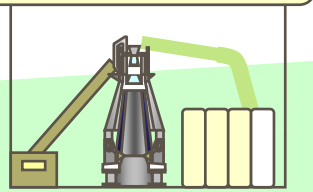
- Energy conservation technologies development and appliation
- New energy and renewable energy
- Tree planting around the world
- Energy and environment technology
  - CO_2 ocean and geological storage
  - Feasible CO_2 chemical and biology capture

Potential technology Contribution to the CO_2 abatement

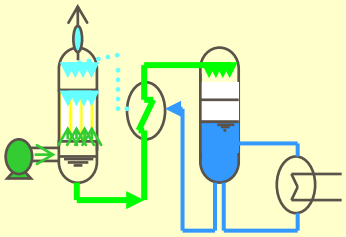


PART II：CO_2 Storage Technology

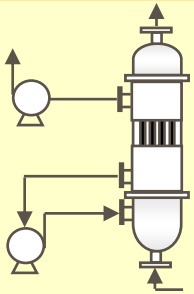
CO_2 separation, re-use and storage system

	Power Plant	Concrete	Steel	Chemistry
Sources				
CO_2	7%-14%	about 20%	about 25%	30-50%
SO_2	0-10ppm	3ppm	50ppm	0ppm

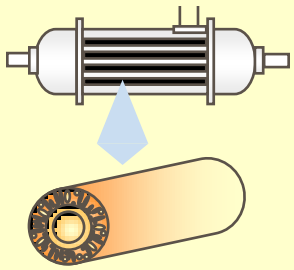
Saparation & Re-use



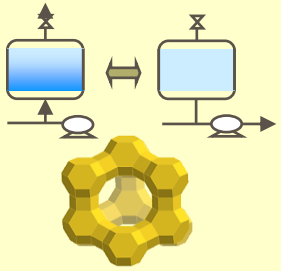
Absorption



Absorption-membrane



Membrane saparation



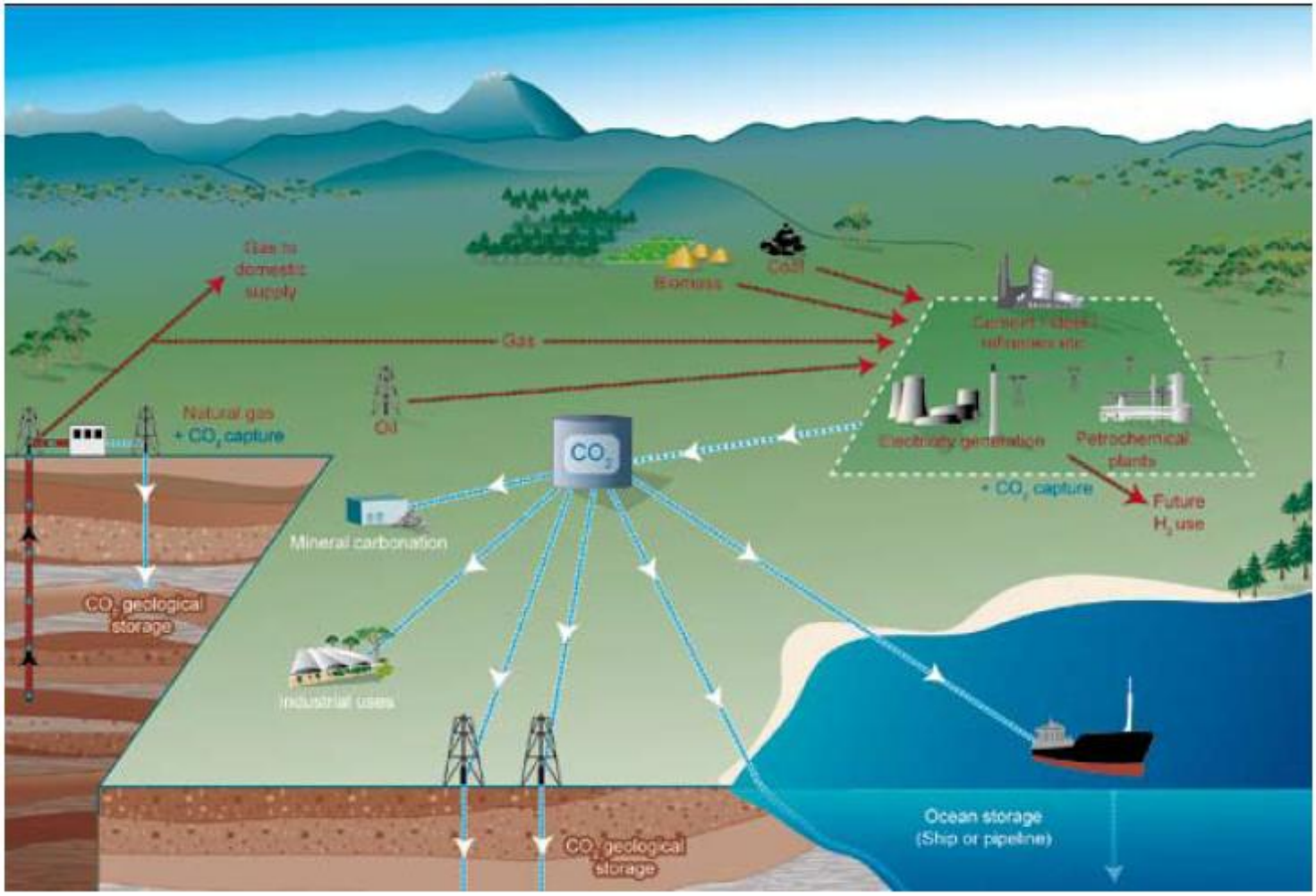
adsorption

Storage

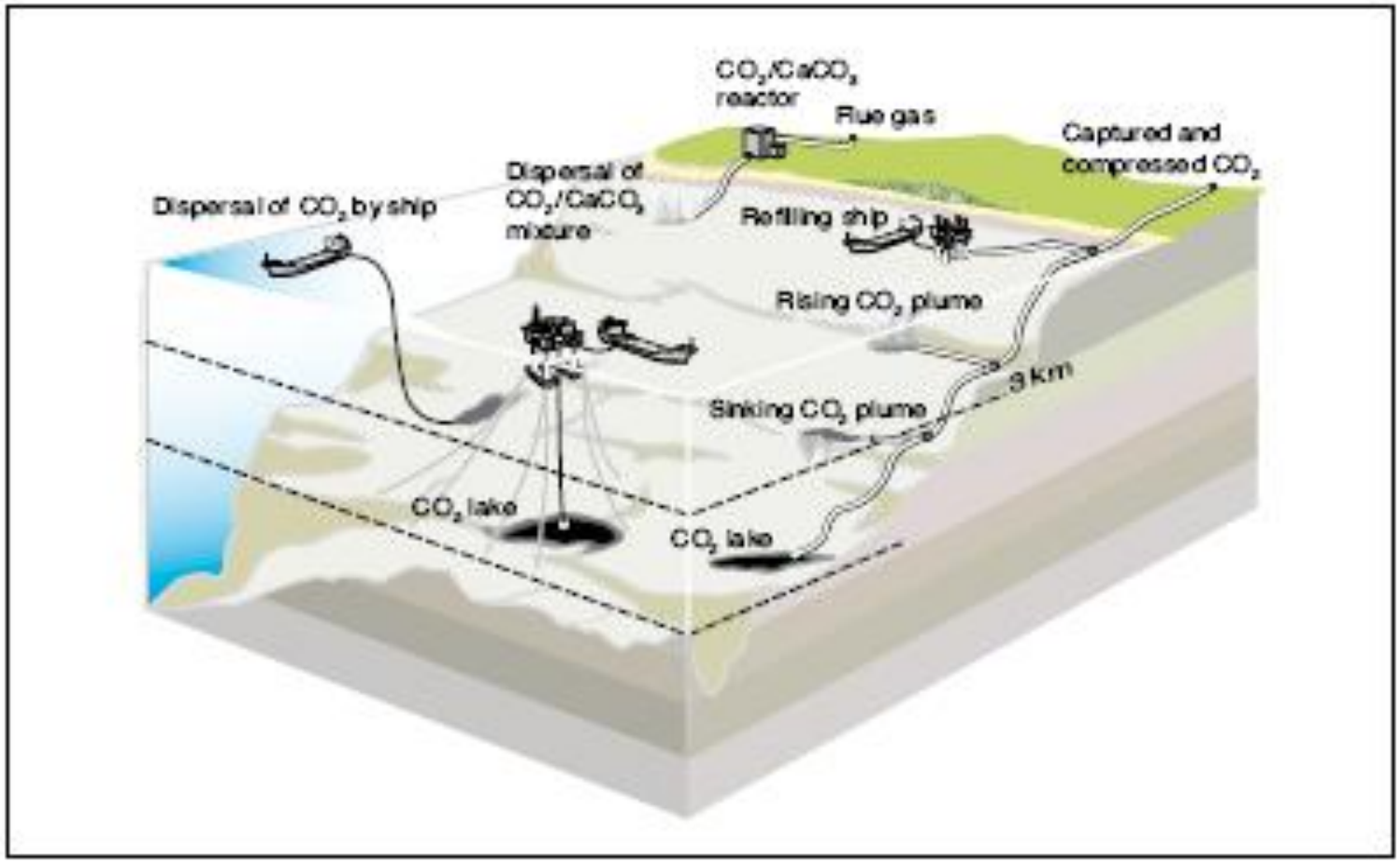
Underground

Ocean

Schematic view of CO_2 Capture and Storage (CCS)



Method of CO_2 ocean storage



Comparisons of CCS technologies

	Cost	Storage capacity	Storage life	Environment compact
Shallow sea dissolution	◎	Small	×?	×?
Shallow to middle sea dissolution	○	Big	Hundreds to thousands of year	○
Deep sea dissolution	△	Big	Hundreds to thousands of year	△
Mineral carbonation	○	Small	permanence	○
Enhanced Oil Recovery/ Enhanced Coal Bed Methane recovery	○	Small	Permanence	○
Saline formations	○	Big	permanence	○

China pays more attention on the green-house gas reduction

China is working on the CCS technology and green-house gases reduction technologies.

National CO2 emmiting（IEA，2000）

Nation	CO_2, Billon ton	percent, %
USA	48.81	23.72
China	26.68	12.97
Russia	21.03	10.22
Japan	10.93	5.31
German	8.78	4.27
India	7.69	3.74
Ukraine	6.11	2.97
UK	5.66	2.75
Canada	4.1	1.99
Italy	4.08	1.98
France	3.62	1.76
Poland	3.42	1.66
Others	51.93	25.24
Total	205.74	100.00

CCS Research Review

International

USA, Japan, Norway, Canada, Australia

项目名称	国家	开始井下注入（年）	日平均井下注入的大致速度（吨CO_2/天）	（规划的）封存总量（吨CO_2）	封存储层的类型
Weyburn	加拿大	2000	3,000-5,000	20,000,000	EOR
In Salah	阿尔及利亚	2004	3,000-4,000	17,000,000	天然气田
Sleipner	挪威	1996	3,000	20,000,000	盐沼池构造
K12B	荷兰	2004	100（1,000 为2006+规划）	8,000,000	增强的气体回收
Frio	美国	2004	177	1600	盐沼池构造
Fenn 大山谷	加拿大	1998	50	200	ECBM
Qinshui 流域	中国	2003	30	150	ECBM
Yubari	日本	2004	10	200	ECBM
Recopol	波兰	2003	1	10	ECBM
Gorgon（规划中）	澳大利亚	~2009	10,000	未知	盐沼池构造
Snøhvit（规划中）	挪威	2006	2,000	未知	盐沼池构造

PART III：Our Work

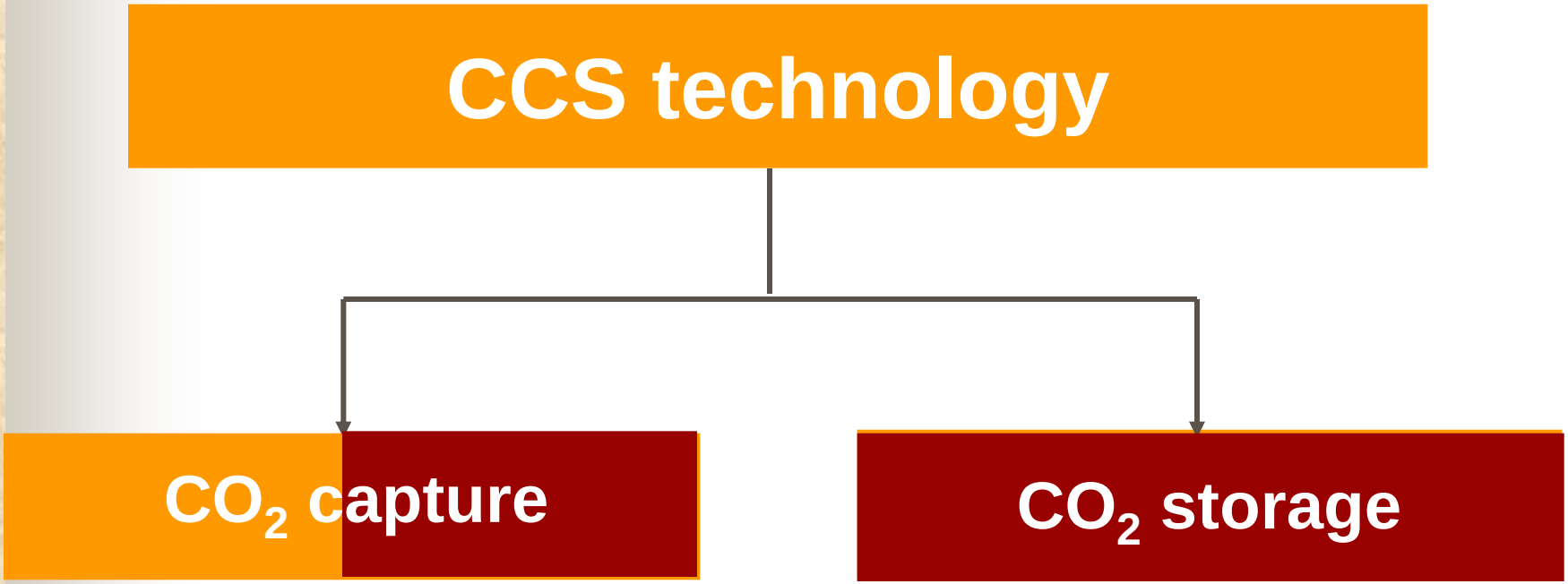
Long-term Research Goal

- **Build a green-house gas emission lab, to carry out research and teach young scientists.**

- **Set up the China CCS research system, and study the advanced CCS technologies suitable to China. Make progress on the CCS key techniques.**

- **Promising young scientists specified in CCS research.**

Recent research topics



CO_2 storage

- Geological storage options
- Fundamental research
- Geological storage process
- location selection
- Feasibility study
- storage capacity
- Security study

Research projects participated

- **Japan National Key Research**

  “Research on the CO2 geological storage”
  2001—2015, 15 billion Yen

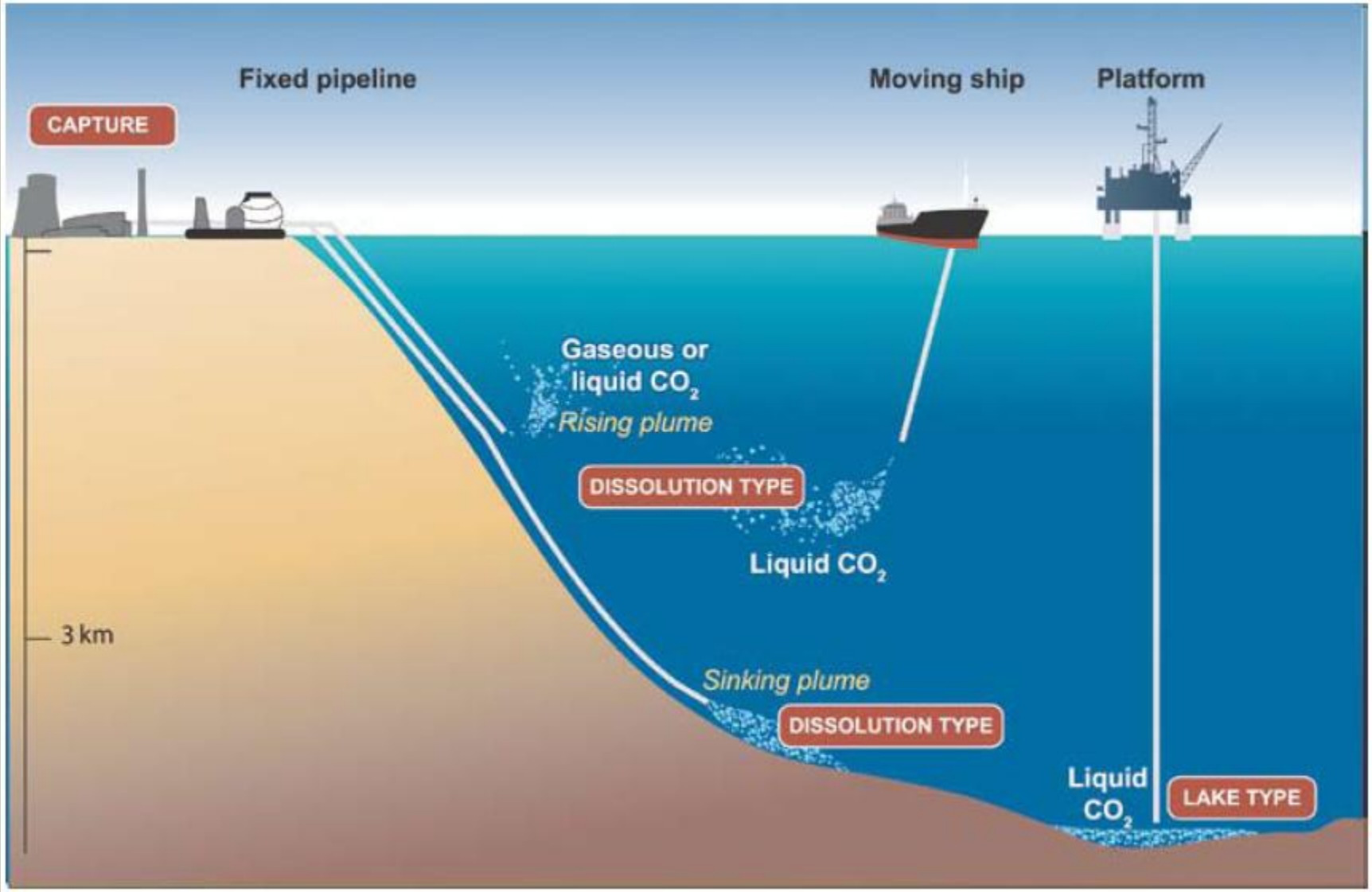
- **Japan National Key Research**

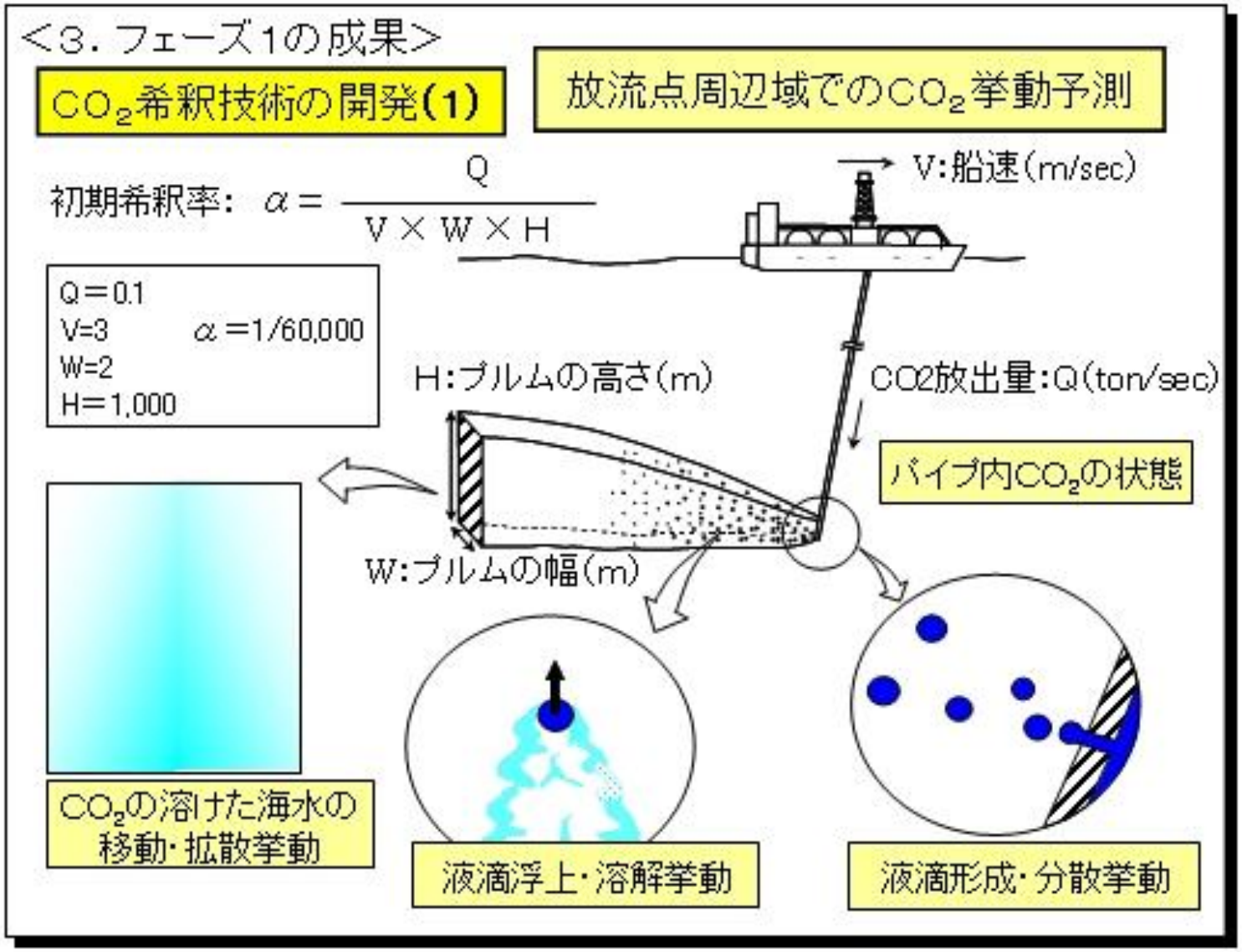
  “Research on the effect CO2 separation to the environment”
  1997—20012, 15 billion Yen.

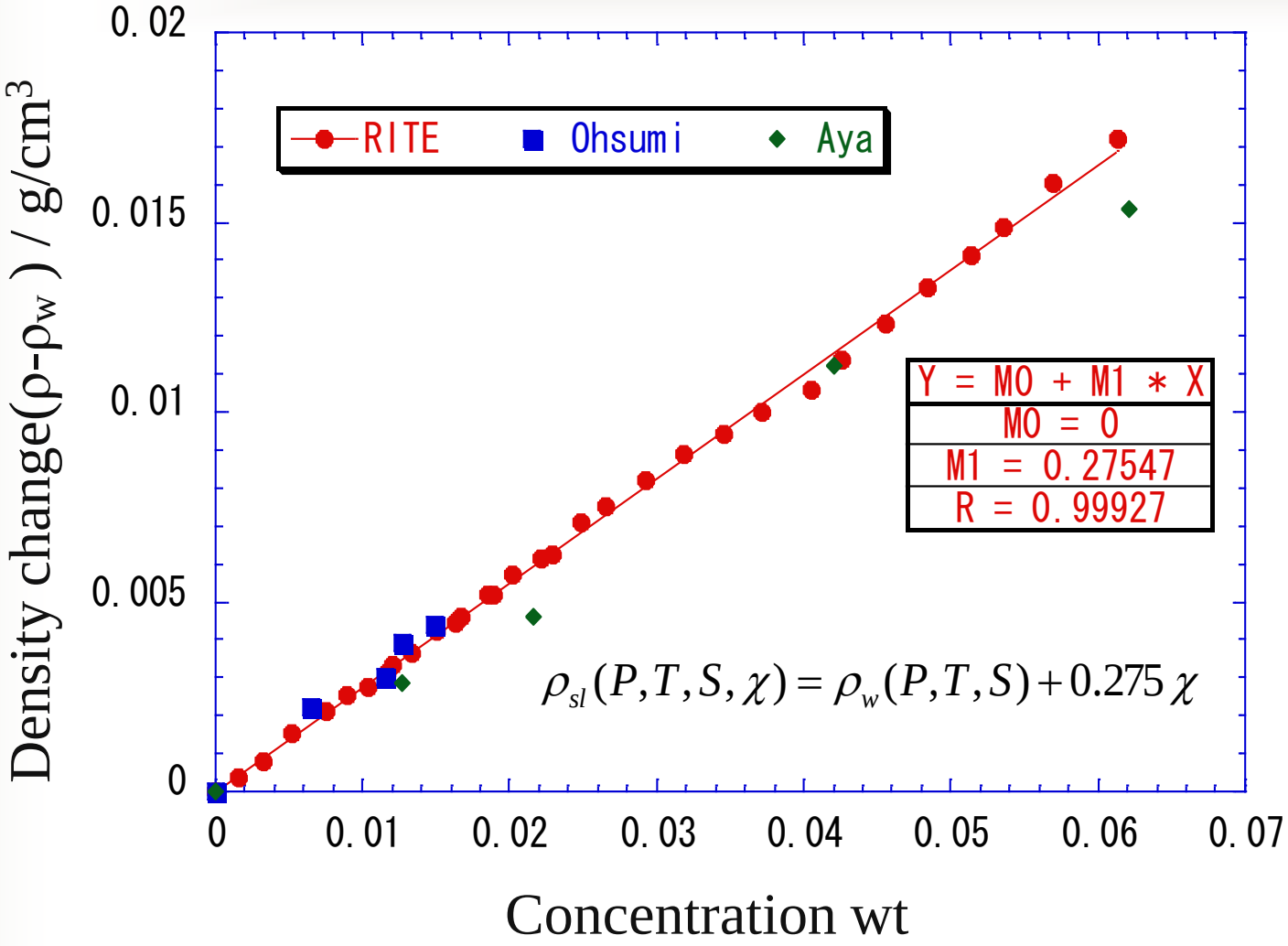
- **Japan NEDO Frontier Research**

  “Research on the CO2 ocean hydrate storage technology”
  2002—2005, 0.35 billion Yen.

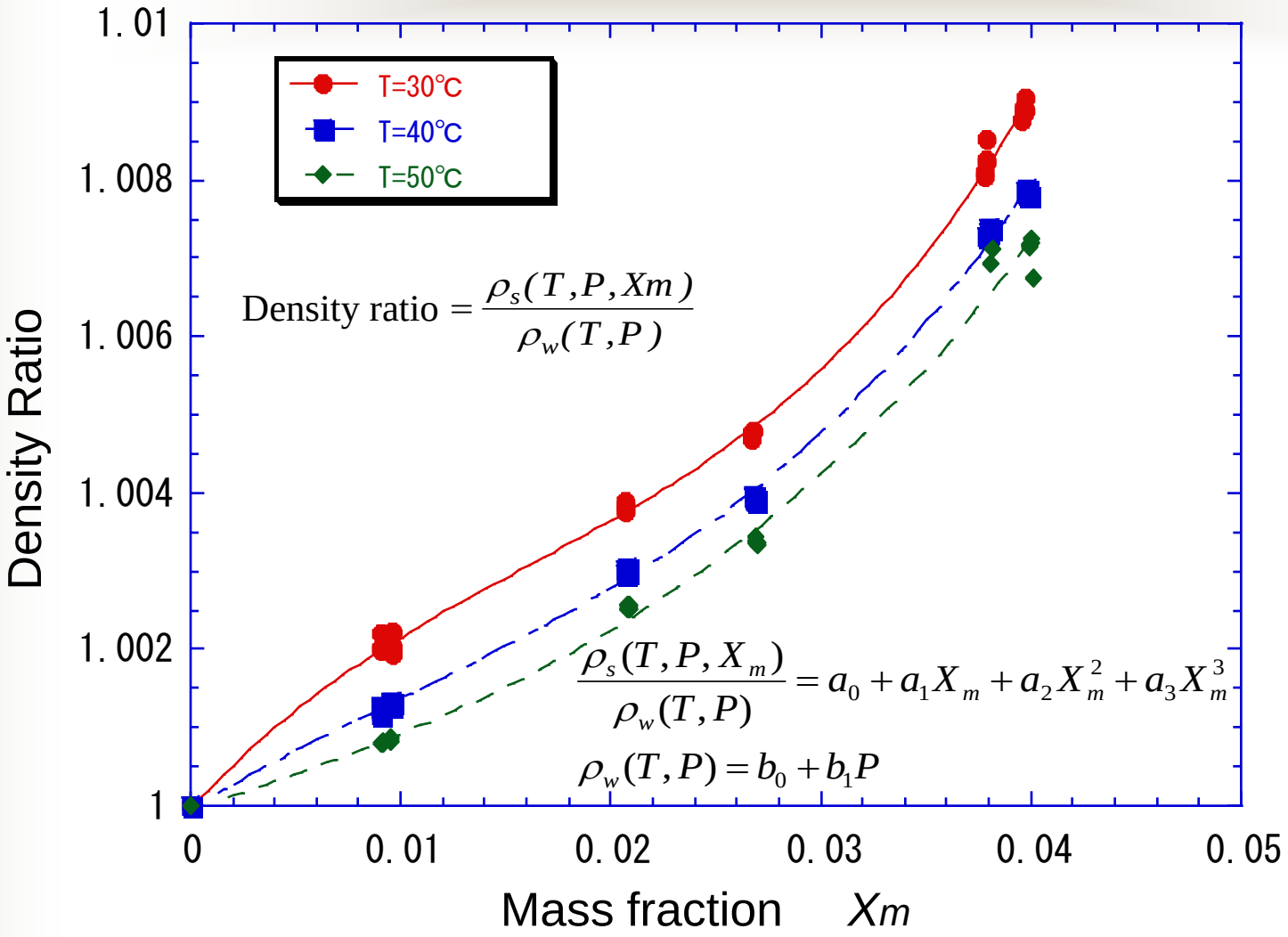
CO_2 ocean storage technology



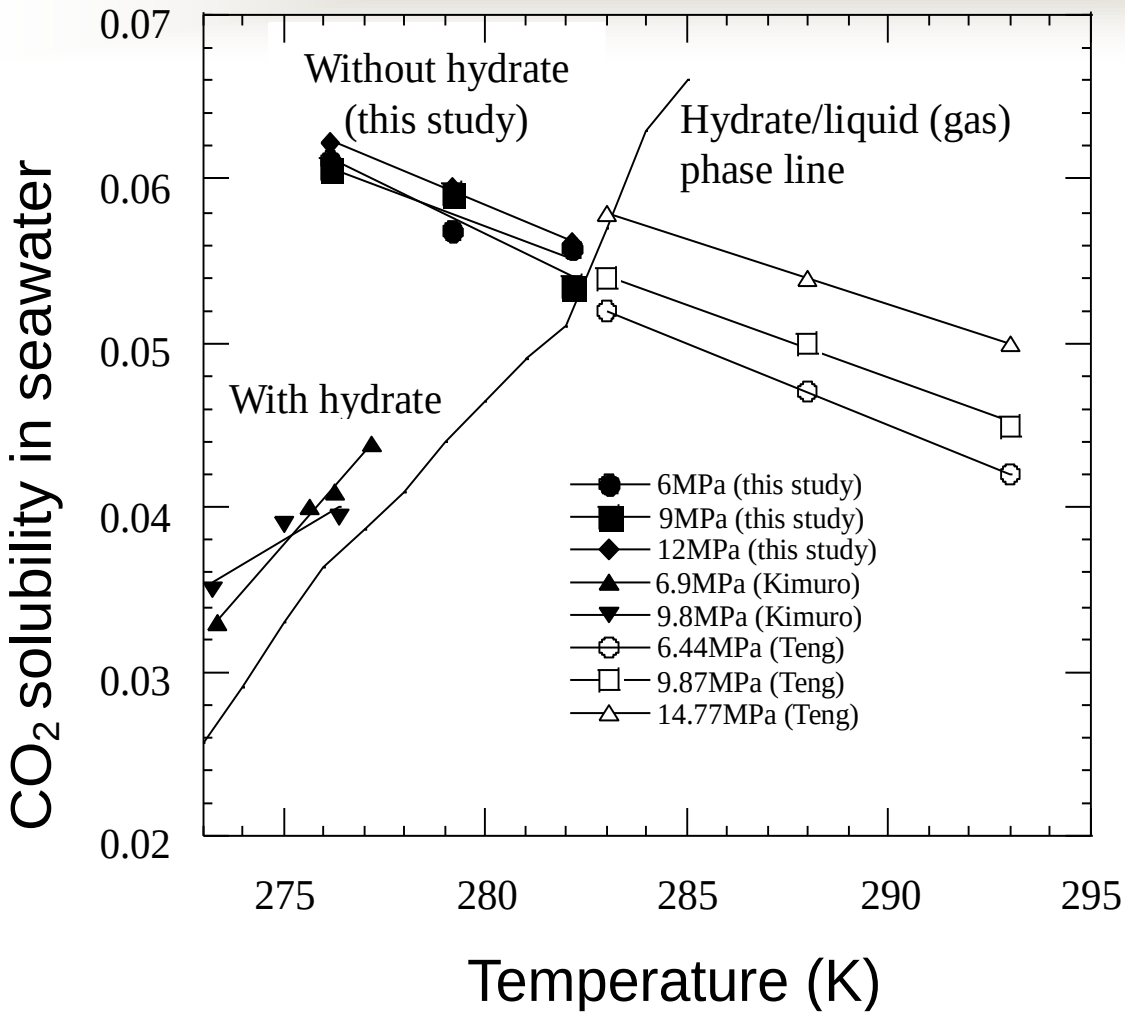

<３．フェーズ1の成果>
CO2希釈技術の開発(1)
放流点周辺域でのCO2挙動予測
初期希釈率: α = Q / V × W × H
V:船速(m/sec)
Q＝0.1
V=3
W=2
H＝1,000
α＝1/60,000
H:プルムの高さ(m)
CO2放出量:Q(ton/sec)
パイプ内CO2の状態
W:プルムの幅(m)
CO2の溶けた海水の移動・拡散挙動
液滴浮上・溶解挙動
液滴形成・分散挙動



Research on the relationship between CO_2 concentration and dissolution



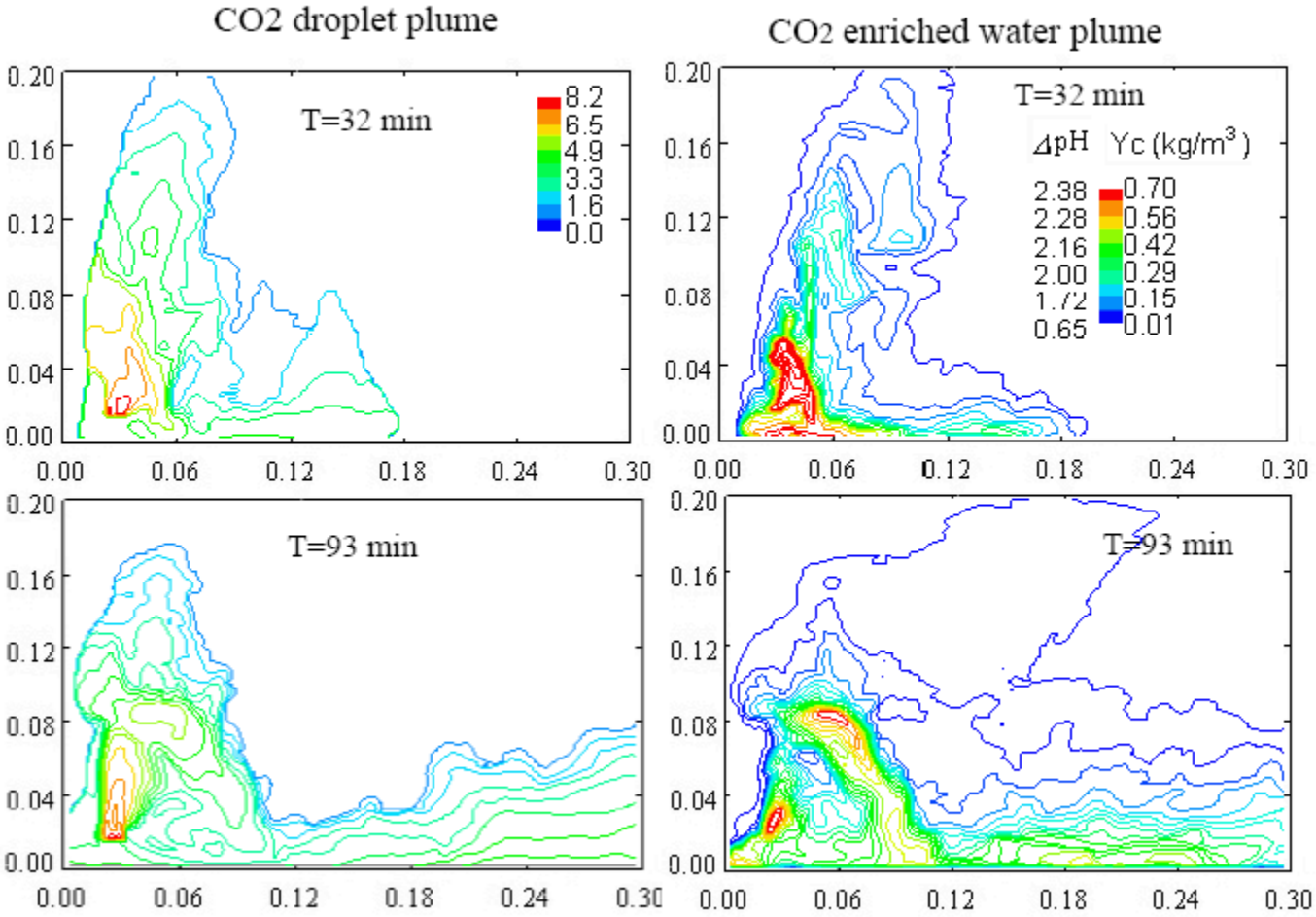
Density ratio (ρ_s / ρ_w) as function of CO_2 mass fraction and the variation with temperature



The expremental results of CO_2 solubility in seawater obtained from this study and from literatures

CO_2 plumes properties in deep ocean (a)

[leakage rate of 100kg/s]; Chen et al *JGR* 2005



Depth: 1500m; Target ocean: West Coast of Hawaii Island (19 43.3624'N, 156 04.605W)

Working Experience

Published Papers

1. Tao Lu, Peixue Jiang, Shengqiang Shen, Numerical and Experimental Investigation of Convective Drying in Unsaturated Porous Media With Bound Water, Heat and Mass Transfer, v.41, n.12, 2005, p.1103-1111. **(Sci, Ei)**
2. T. Lu, S. Q. Shen, Numerical and experimental investigation of paper drying: Heat and mass transfer with phase change in porous media, Applied Thermal Engineering v.27,n.10,2007, 1248-1258.
3. S.Q.Shen, Prediction of temperature distribution in porous ceramics in process of regeneration with micro-wave energy, Second International Conference on Combustion Technologies for a Clean Environment, Lisbon, Portugal, 19-22 July 1993
4. T.Lu, P.X.Jiang, S.Q.Shen, Numerical and experimental investigation of convective drying in porous media, The 6th International Symposium on Heat Transfer, Proceedings of the 6th International Symposium on Heat Transfer, p.397-402, Beijing, China, June 15-19, 2004
5. Yongchen Song, Baixin Chen, M. Nishio, and M. Akai, 2005, “The study on carbon dioxide seawater solution density at high pressure and low temperature”, *Energy*, Vol. 30, 2298–2307. **(SCI)**
6. Baixin Chen, Y. Song, M. Nishio, and M. Akai, 2005, “Modelling near-field dispersion from direct injection of carbon dioxide into the ocean”, *Journal of Geophysical Research*, 110, C09S15, doi: 10.1029/2004JC002567 **(SCI)**
7. Someya S., S. Bando, Y. Song, M. Nishio, 2005,“Measurement of CO2 solubility in pure water and the pressure effect on it in the presence of clathrate hydrate”, *Int. Journal of Heat and Mass Transfer*, Vol. 48, 2503–2507. **(SCI) (EI)**

8. Someya S., S. Bando, Y. Song, Baixin Chen, M. Nishio, 2005, “DeLIF measurement of pH distribution around dissolving CO2 droplet in high pressure vessel.”, *Int. Journal of Heat and Mass Transfer*, Vol. 48, 2508–2515. **(SCI) (EI)**
9. Yongchen. Song, Baixin Chen, M. Nishio, and M. Akai, 2004,“Measurement of clathrate hydrate precipitation from CO2 solution by a nondestructive method”, *American Mineralogist*, Vol. 89, Aug-Sept., 1247-1253. **(SCI)**
10. Baixin Chen, Y. Song, M. Nishio, and M. Akai, 2004, “A Eulerian-Eulerian physical-biological impact model of zooplankton injury due to CO2 ocean sequestration”, *Journal of Oceanography*, Vol. 60. 797-805. **(SCI)**
11. Baixin Chen, Y.Song, M. Nishio, and M.Akai, 2004, “A hybrid numerical model system of LCO2 and CO2 enriched seawater dynamics in the ocean induced by moving-ship releasing”, *Energy*, Vol. 29. 1487-1497. **(SCI)**
12. Baixin Chen, Y. Song, M. Nishio, M. Akai, 2004, “Large-eddy simulation of small-scale ocean turbulence coupled with buoyancy plume”, *Direct and Large-Eddy Simulation V, ERCOFTAC SERIES*. Kluwer Academic Publishers, p. 253-260.
13. Y. C. Song, B. X. Chen, M. Nishio, and M. Akai, 2004, “*Experimental Study of Dissolution Rate of A CO2 Droplet and CO2 Solubility in High Pressure and Low Temperature Seawater with hydrate free*”, in Proc. of the 23rd Int. Conf. on Offshore Mechanics and Arctic Engineering, ASME-OMAE 51133. **(EI)**
14. Baixin Chen, Y. Song, M. Nishio, and M. Akai 2004, “Numerical prediction of the effects of oceanic flow characters on the evolution of CO2 enriched plumes”, *in Proc. of the 23rd Int. Conf. on Offshore Mechanics and Arctic Engineering*, ASME-OMAE 51103. **(EI)**

15. Y. C. Song, B. X. Chen, M. Nishio, and M. Akai, 2004, "*Liquid CO2 Permeability measurement of CO2 hydrate-bearing sediments*" in *Greenhouse Gas ControlTechnology*, J. Wright & J. Gale eds., Elsevier Science,567-571.
16. S. Someya, Y. C. Song, & M. Nishio, 2004, "*Laser-Dye Imaging of the pH Field in a Laboratory Experiment*" Journal of Oceanography**,** Vol. 60, 789-795.**(SCI)**
17. Y. C. Song, B. X. Chen, & M.Nishio, 2003, "*Measurement on CO2 Solution Density by Optical Technology*", Journal of Visualization, Vol.6, No.1, 41-51. **(SCI)**
18. Nishio M., Song Y., and Baixin Chen, 2003, "Measurement of CO2 solution density under deep ocean and underground conditions", In: *Greenhouse Gas Control Technology*, J. Gale & Y. Kaya Eds., Elsevier Science, 1675-1678,
19. B.Chen, Y. C. Song, and M. Nishio, 2003, "*Numerical Simulation of the Inner Structure of Two-phase Plume Formed in Stratification Environment*", J. of Visualization, vol. 6, No.1, 9-21. **(SCI)**
20. B.Chen, Y. C. Song, and M. Nishio, 2003, "*Large-eddy Simulation on Double-plume Formation Induced by CO2 Dissolution in The Ocean*", Tellus (B), Vol. 55 (2). 723-730. **(SCI)**
21. Y. C. Song, Baixin Chen, M.Nishio, M. Akai, 2003, "Density change ofunderground water due to CO2 dissolution", Proc. of 226th ACS National Meeting. **(SCI)**
22. Baixin Chen, Y. C. Song, M. Nishio, and M. Akai, 2003, "A two-step mechanism model of Anothite dissolution in CO2 solution", Proc. Of 226th ACS National Meeting. **(SCI)**
23. Y. C. Song, M. Nishio, Baixin Chen, 2002, "*Measurement of the Density of CO2 Solution by Mach-Zehnder Interferometry*", Annals of the New York Academy of Science, Vol.972, 206-212. **(SCI)**

24. Baixin Chen, M. Nishio, Y.C. Song, and M. Akai, 2002, "*Numerical Visualization of two-phase Plume Formation in Stratification Environment*", Annals of the New York Academy of Science, Vol.972, 285-291. **(SCI)**
25. W.Z. Li, Y.Y. Yan and J.M. Smith, 2003, A numerical study of the interfacial transport characteristics outside spheroidal bubbles and solids, Int. J. Multiphase Flow, 29 (3) 435-460, **(SCI& EI).**
26. W.Z. Li, Y.Y. Yan and J.B. Hull, 2003, The propagation of temperature and concentration fields around a deformed gas bubble rising in a quiescent hot or bi-solution liquid, Int. J. of Numerical Methods for Heat Fluid Flow,13(8), pp940-963, **(SCI& EI).**
27. W.Z. Li and Y.Y. Yan, 2002, An alternating dependent variables (ADV) method for treating slip-boundary conditions of free surface flow with heat and mass transfer, Numerical Heat Transfer (An International Journal of Computation and Methodology), Part B, 41 (2), pp. 165-189. **(SCI& EI).**
28. W.Z. Li and Y.Y. Yan, 2002, A direct-predictor method for solving terminal shape of a gas bubble rising through a quiescent liquid, Numerical Heat Transfer (An International Journal of Computation and Methodology), Part B, 42 (1) pp. 55-71, **(SCI& EI).**
29. Bo Yang, Weizhong Li，A Numerical Simulation of Effects of Wall permeability on Heat and Mass Transfer in Porous Medium with Constant Heat Flux Boundary，*5th International Symposium on Multiphase Flow, Heat Mass Transfer and Energy Conversion，Xi'an, China, 3-6 July 2005.*
30. Y. Y. Yan and W. Z. Li, Numerical modeling of a vapour bubble growth in uniformly superheated liquid, *Int. J. Numerical Methods for Heat & Fluid Flow,16(7*),764-778,(2006). **(SCI& EI).**
31. 李维仲，陈聪，LJ流体自扩散系数及其与温度关系的分子动力学模拟，*热科学与技术*，5(2)（2006）,pp101-105。

Group members

Position	Professor	Associate Professor	Assistant Professor	Total
	6	2	2	10
Degree	Ph.D	Master	Bachelor	Total
	9	1	0	10

Additional, there are 1 honored professor, 2 visiting professors, 4 PhD students, 8 master students.

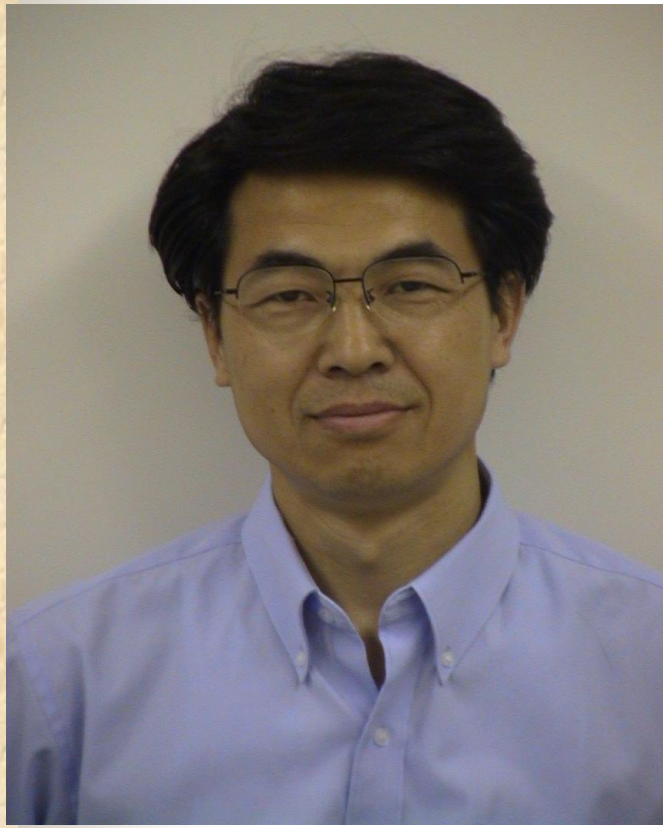
Yongchen Song Ph.D, Professor

Visiting Professor and Researcher of Japan National Environment Institute and NEDO from 1996.

From 2004, Dean of School of Energy and Power Engineering of Dalian Univ. of Techn. Member of the China 863 Project council.

Participate or in charge of 12 national key projects, such as 973, 863 and National Science Foundation projects.

Published more than 80 papers.



Baixin Chen, Ph.D, Professor

Visiting professor of NEDO, from 1998.

Editor council member of Japanese journal of the Ocean Science and Technology.

Writer of IPCC CARBON DIOXIDE CAPTURE AND STORAGE.

Head of school of Energy Science and Engineering of Dalian Univ. of Techno., from 2007.

Published 120 papers.

Weizhong Li Ph.D, Professor

Specified in the research of phase change heat transfer and mass transfer mechanism.

In charge of more than 20 science projects, including the China Science Foundation projects. Published more than 60 papers.

Shengqiang Shen Ph.D, Professor

Executive Chief Editor of Thermal Science and Technology.

Specified in the fluid flow and heat transfer.

In charge of more than 40 science projects, include the China Science Foundation projects.

Published more than 130 technique papers.

Laboratory

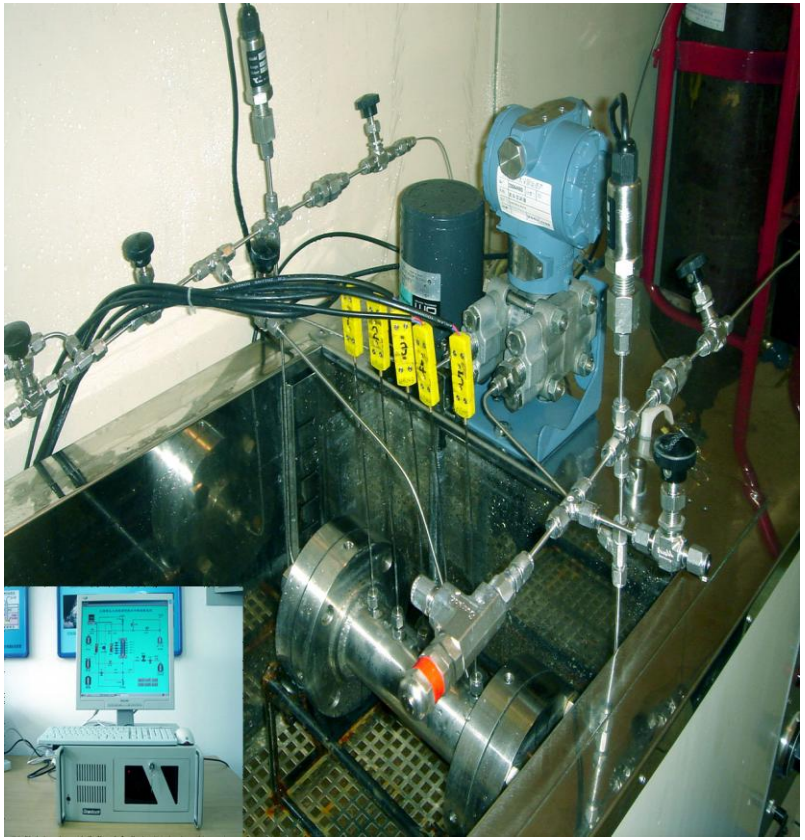
3 Labs

- **Ocean Energy and Energy Conservation Lab**
- **Power Engineering Lab**
- **New Energy and Energy Reservation Center**

We have

- **Nuclear Magnetic Resonance Image System**
- **magnetic suspension mass spectrometer**
- **High-speed photograph system**
- **Other routine equipments**

Equipments



Relevant Supported Projects

- **China National Key Foundamental Research project（973）**

Green-House Gases Geological Storage and Resources Utilization in the Increasing Oil Mining and Collection
2007-2011，budget :1 million RMB

- **China Nature Science Key Project**

Study on the Super-Critical State CO_2, Water and Crude Oil Transport Characteristics in the Dense Porous Media.
2008-2011，budget: 1.8 millon RMB


Thanks for your attention !
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